How architectural rules make room for creativity: an ontology-driven analysis

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Abstract. Architecture is said to be a science and an art as it is about construction and communication, form and matter, rule and novelty. The paper begins by looking at how architecture has been discussed in the literature from the words of both architects and theoreticians. This leads to identify a set of architecture's core elements, in particular regarding the meaning of rules, and a notion of meta-rule about composition choices in architecture. It follows that the act of creativity has a way to manifest itself into this domain via the described interplay between rules and meta-rules.

The main contributions of this paper are an ontology-driven discussion of architecture from the given perspective, and an initial proposal on how to isolate and understand architectural rules. The goal is to show that there is a way to model these elements and their interactions, that is suitable for future integrations into formal systems. This, we believe, can turn architectural creativity into a subject for formal representation and exploitation.

Keywords. Architecture, Rule, Creativity, Representation, Ontology

1. Introduction

Architecture embraces and integrates several domains: design, civil engineering, material science, social science, aesthetics etc. making it an inherently interdisciplinary domain along many others like engineering, economics and medicine, just to name a few. Yet, architecture is interdisciplinary in a stronger sense as it is, has been and aims to be at the same time a science and an art [7]. This latter claim may be understood in different ways but one thing is clear: it puts doubts on whether formal systems can practically and effectively deal with architecture.

The creation process in architecture starts with the request of the design of a building or the (re-)organization of an area, and ends with the implementation of the chosen solution. Overall it is a complicated process and we focus on the first part only, namely, the design process. This restriction in focus highlights the goal of the paper, that is, to characterize two core factors in the architect's practice: architectural rules and creativity. Generally speaking, we aim to shed some light on the relationship and integration of these elements, and on their connection to architectural types, even though we will not tackle explicitly the latter notion in this paper. Also, we do not deal at this stage with the

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larger issue of computational creativity, nor with the problem of designing AI tools for creativity. The interested reader can look at approaches like [26] for practical exploitations into these issues. Our goal here is to understand how the architect 'understands' the rich framework of architectural rules, and how she can express her creativity in such a framework. In our view, only once this analysis is completed and validated, it will be possible to meaningfully take into account the perspective of computational creativity within architecture.

The design process in architecture is usually divided in subphases starting with the setting of the project requirements, followed by the generation and selection of the idea conception, and finally ending with the complete drawing of the design entity. These steps are usually seen as forming a process that takes place in the cognitive realm of the architect as well as in physical reality: the acts of imagination determine how to conceptualize the entity and to draw it, the actual drawing realizes the mental image and provides an objective perspective which is used by the architect for the subsequent artistic and/or practical (re-)elaboration in a sort of feedback loop that converges to a solution. This high level description could apply to any modeling process, for instance those in industrial design, except for the special implications of the term 'artistic'. Wittgenstein, a philosopher and a practitioner of architecture and design, highlights this as follows: "the image of the world is a practice: it offers different ways of comparing and acting, so rules are useful and necessary but at the same time they are changed by the practising and the designing action, as the riverbed moves with the flowing water". This key feature of architecture design is highlighted by Pisani [19] when he states that *architectural rules change while doing architecture*. This view raises some question. How can one understand rules in architecture? How can one make sense of the relationship between 'using rules' while 'changing rules'? In this paper we set the basis of a framework that, we believe, can answer these questions. The result we present here relies on the work of famous architects and uses the methods of ontological analysis [11,2] for their analysis and comparison.

Structure of the paper: in Sections from 2 to 4 we look at architecture, its domain and how to understand its rules and practice as discussed by the practitioners (architects) and the theoreticians (architects, historians and philosophers). These sections present the words of the practitioners with their evocative, sometimes metaphoric language. Building on observations raised during the analysis of the experts, a novel classification of architectural rules, guided by our ontological analysis, is developed in Section 5. Section 6 concentrates on the notion of meta-rule, that is, rules that guide changes in architecture and open the domain to the manifestation of creativity. Section 7 concludes highlighting potentialities and limitations of this work, and indicates future steps.

2. What is Architecture?

Practitioners of a discipline may disagree on methodology and relevance of the results, but share a common understanding of the discipline itself. This is not so in architecture. Fisher questioned the understanding of architecture in an attempt to identify its core nature. "What sort of enterprise is architecture?; does architecture have essential features?; what kinds of things does architecture make?; is architecture always, only sometimes,

or never an artform?; what distinguishes architecture from other artforms?; and does architecture include all built structures?" [9]. Architects and theoreticians have defended different positions on these topics. For instance, Louis Kahn [13] claims that "architecture is what nature can't do" and "architecture is the thoughtful making of spaces", while Le Corbusier [5] insists that "architecture is over the functions". Others [1,23,4] recognise in architecture the utmost expression of human culture, which is full of poetical reverberation.

One can claim that an object is architectural when it features forms which are proper to the domain. This means that an object is architectural independently of the community that judges it. Within this view, often one assumes that forms proper to architecture can be chosen from a stylistic menu, leaving architects freedom to uphold possible forms or design answers [9]. Yet, proposals in the opposite direction are also defended, for instance by claiming that what distinguishes architecture is its lack of replaceability, its role in the narrative of one's (individual or community) life.

Objects made in architecture have to accomplish the ordinary goals, e.g. satisfy social needs, and to give a sense of beauty and surprise. Via their presence, architectural objects change the sense of space and innovate the modalities for an aesthetic fruition of it. This is obtained by exploring new ideas, which then go through a process of 'sedimentation' before their actual exploitation in architectural design. Once sedimented, they return (consciously or else) in the architect's work as signatures, reminiscences, even phantoms, and strive to find a place. The result of this process, interior to the architect, is found in the interplay among the built entity (its objective properties), the subjective view of the architect (her intention or vision of the created entity), and the community that "experiences" it. We take this interplay to be the real meaning of architecture. The surprise, the wonder raised by the built entity, continues in time primarily in the (perhaps subtle) perception of the harmony of parts and of proportions, in what has been designed to be a flexible space, i.e., a space that interacts, adapts and regenerates with the changes in the community living it and around it.

3. Understanding Architecture

Over the centuries architects have tried to understand the complexity of their knowledge domain and to systematize, or at least to put some order in, the key elements that are at the core of architecture. This effort led to a clarification of different views and related approaches, and highlighted some regularities.

Architecture is based on a corpus of knowledge and rules. Architectural knowledge and rules are often discussed as forming a proper theory. Yet, a comprehensive statement of this theory does not exist. One reason is that architectural theory aims to codify practical and theoretical knowledge. Something similar, although at a simplified level, happens in engineering where design theory splits in a number of sub-phases, each requiring specific theoretical and practical expertise. The interesting point is that the engineer is thought of as a neutral player in the design process, a figure in the background. The architect instead is in the foreground, her presence is felt in any attempt to understand what is going on during the architectural process and so is when one tries to understand architecture itself. Any prescriptive, even didactic, expression manifests the architect's

intentionality to promote a given or new way to do architecture, and to ground her architectural practice in moral, social, psychological, or theoretical bases [9].

Producing is primarily a physical act; composing is primarily an act of the mind. Architectural objects are the outcome of composing and producing in a context that mixes art and science. This happens in artistic disciplines where the generation of internal rules, grammars and techniques, leads to results that go beyond the simple concretization of insights. Creativity can very well be thought of as a rational activity [8] or as a property of the agent [10]. Nonetheless, architecture cannot be properly explained nor understood without referring to cognition, to intentionality and to (personal) memories [17].

4. Architecture, Rules and Practice

According to Schon [24] the reflexive architect works by continuously asking herself the question: 'what if?'. The view of activities as receptive actions (knowing in action and reflection in action) wanted to depart from the idealization of the practitioner as a (rational) problem solver, a view defended to some extent in [25] (on the role of the 'what-if' question in problem solving see also [20]). To answer the 'what if' question, one has to image cases alternative to the present and to the immediately foreseen, and this act of imagination is based on the distinction between what is expected (or even desired) and what is possible. The reflective architect uses the rules of its domain to extend her thinking from the class of expected cases to the larger class of possible cases. When facing a new or unique problem which falls outside known categories, this investigation becomes a process of artistic design. The structure of this procedure is like a reflexive dialogue that permeates all the design activities. The designer creates a long plot of moves, each group of moves associated with multiple assessments [21].

Analogy, re-combination and re-elaboration are continuously applied to the design due to the input of different stimuli, including the personal memories of the architect [17]. Rules learned and interiorized during the architect's training seem, by themselves, capable to enforce livability into the designed objects. This means that the architect relies on a corpus of rules, informally referred to as 'the state of art', where all different layers of meanings, effects and functionality of the designed object find a place and integrate. These layers must embrace the style, the use, the intention of the designer/architect, but also attain the needs and the expectations of those who will live in and use those spaces.

The rules we aim to study are not related to the interaction among natural laws, material and civil engineering (e.g. requirements to ensure a dwelling's stability), they are essentially architectural in the sense of being the architect's choice to create an object (or space) of architecture. An architectural rule about compositional choices is not just a constraint expressed once for all in some, formal or natural, language. Following these architectural rules does not mean to apply them at face value since the same rule can find its place at different architectural levels. The term 'architectural grammar' indicates a corpus of rules which is both a summary of the knowledge of architectural elements and of the rules for an appropriate use of these elements according to the task to accomplish [15]. Given a grammar of this kind, architects are not much interested in its abstract meaning but in its interiorization (the practice they see in it and how they interpret it) and the operational consequences: they play with ways to interpret the grammar to test the constraints it imposes. The totality of the rules determines the *initial space* available to

the architect and to the exploitation of her creativity. The rules are not just constraining the modeling space, they are also part of it. Being part of the initial space, the architect can play with them, change them and, thus, change the space itself. This interplay brakes the boundaries between what is to be constructed and what is to guide the construction, and happens in the mind of the architect where her project, personal and architectural memories combine.

Both the corpus and the meaning of the architectural grammar that the architect embodies, change over time under the pressure of memory and of the instances of architectural design that the architect accumulates sketching possible solutions. The meaning of a rule about composition choices for an architect is what is learned when the rule is incorporated into her thinking and is modified into her acting. In this setting the understanding of the interaction between the concepts of rule and of meaning is challenging and is an issue that we do not investigate here as it is rooted in the view of architecture as an art, and of the architect as a cognitive agent.

The architectural rules that constrain composition choices are not rules about reality nor about the laws that govern reality. For this reason, these rules do not need to bend to reality or to coherence. They are, logically and ontologically speaking, arbitrary, contingent to the state of the discipline and bound to be violated. Rules' arbitrariness is here essential: in architects' words they determine the meaning without being the subject of any specific meaning [19]. Contradictions can arise only across rules, not in the relationship between a rule and reality (see [16, pg. 116,119]). Interestingly, one may even not know the rules of the language, nor be aware of them and still be able to identify them [27]. When the rules are known, there is a conscious effort to change, adapt or reinterpret them, perhaps minimally but enough for the novelty to be recognizable and acceptable as in architecture communication must be successful. This can be called *assonance* and assonance-driven changes are one of the ways creativity manifests itself in architecture.

5. An Ontological Organization of Architectural Rules

Our approach relies on the use of ontological methodologies to detach the analysis of architectural rules from the traditional viewpoint. Taking a fresh look at these rules, we reach a novel proposal for the classification of architectural rules. More precisely, we are not interested in classifications based on historical development, economic considerations or engineering functionalities. This means that we are not after rules as typically expressed in an architectural textbook. Instead, we look at the very elements a rule regulates to get the gist of its message.

Our assumption is that even though the architect may interpret a rule in different ways, the type of entities to which the rule applies should not change. If these change, we take it to be a different rule. Based on this, we also make the assumption that complex architectural rules can be restated in terms of combinations of rules falling into our classification. This latter assumption is actually justified by the adoption of a foundational ontology. Here we do not investigate this issue further.[2]

[2]The claim is also supported by the practical experience as architect of one of the authors. However, note that there is a large variety of architectural rules across history and it is hard to make a definitive statement on this issue. Also, the topic is further complicated because some rules are primarily practice-based and only informally presented.

Framing rules. Since architecture pivots around the construction of a physical object or the organization of a physical space by adding / modifying objects in it, a class of rules frames the objects as a whole, the understanding of the design space and the aggregation of surfaces and features. These are general rules, like the golden rule, that guide the tension between the parts of the object(s) and their place in the physical space, they help to find the point of reciprocal equilibrium towards the attainment of a global internal and external harmony. Ontologically these rules focus on regularities among shape and size of physical objects (and/or their parts) possibly including the position of these objects in space. We call these framing rules.

Quality rules. A dwelling is a complex system with many features: from the height to the extension, from the color to the texture of the material. A second class of rules constrain other qualities of the physical object to be. They control the regularity of the dimensions of surfaces and volumes, the coordination of flowing / broken spaces and, more generally, a coherence in the 'narrative' of the object and its space. The quality can be decided apriori and calculated to ensure, e.g., environmental control of the space (temperature, acoustics, dispersions), aesthetics which is primarily about the lines that close the spaces (curve, straight) and texture that animates surfaces, quantity of transparencies or openings. Ontologically these rules focus on relationships across qualities in order to ensure a determined perception of the environment. We call these quality rules.

System rules. Since the architectural object is a system, some rules guide the interaction and disposition of its parts including the relationship between surfaces, volumes, their reciprocal articulation, and the overall impact of the entity as a whole. For instance, areas dedicated to technical installations should naturally encompass the interactions across the space and system they serve. Ontologically these rules look at the object as a whole formed by a network of interacting components. These are called system rules.

Location rules. The architectural object is mainly an object in a place so that it is never thought in isolation. The idea of how the building will look like in its environment guides the design from the beginning and the result is strictly tailored to that specific physical place. Some rules determine the harmony an architecture should create with respect to its environment [3]. For example, a rule may posit that the new building should look like it has always been part of the landscape. Ontologically these rules control the relationships between the object and its environment. We call location rules the rules that guide the ecological harmony between the building and its environment.

Perception rules. The architectural object is not only a physical object but a place that is seen and recognized. This aspect is the focus of the rules that control how the object should be perceived given its position and design. While rules of proportions are idealized, here we find rules about perceived proportions (perceived with the eyes, with the ears, with the touch) that help to control the observer's sense of balance. These rules can make an object look lighter, give the feeling that the building aligns with the surrounding environment, or suggest an affordance for that building. Ontologically, these are rules that guide how an observer should perceive the object (and the space around it) depending on her location. We call these perception rules.

Function rules. As the design object has also functional purposes (house, hospital, bridge, factory etc.) and social relevance (a town hall is a symbol of ruling and control, a hospital of caring, a square of freedom and meeting), two further rule classes are

Class	Topic of the rules	Example
Framing	the tension across the parts, harmony	Golden rule, the Modulor scale
Quality	the physical and aesthetic qualities of buildings	Color, open/close space harmony
System	the relationship and interactions across parts	Usability, integration metrics
Location	the integration of building and environment	Ecological harmony
Perception	the perception of the building and its environment	Wellbeing metrics
Function	the purpose of the building	Airport layout
Society	the social role of the building	Town hall symbolism
Living	the use and personalization of the building	Open form rule, social exploitability

Table 1. Ontology-driven classes of architectural rules.

distinguished: function rules and society rules. Function is about the specialization of a space as suitable to perform some types of activity and is controlled by what we call function rules. Ontologically, these rules help to indicate and control possible uses of and interactions with the object.

Society rules. There are rules aimed to give the object an appearance that matches its symbolic significance. They apply also to iconic landmarks (Tour Eiffel, Statue of Liberty) and, generally speaking, depend on the cultural and social organization of a population. Ontologically, these rules are about the role the object is supposed to play in the social and cultural system. We call these society rules.

Living rules. Finally, since the design object is a place for living or an entity to live with, let it be a house, a square or a city gate, another set of rules are devoted to the organization of the living and the practices for interacting with the object. Ontologically these rules control the development of social practices and aim to guide how and to what extent the community can transform/adapt the object. We call these living rules.

As architecture is an evolving domain that continuously influences and is influenced by culture and society, the number of rules that we find in these classes keeps extending. In textbooks these rules are often intermixed with other aspects (from material properties and construction techniques to engineering constraints or even legal regulations) or are collected in families that identify practices, cultures, styles and regulatory systems. Most of these groups are studied for their historical relevance so that we know about their introduction, meaning, motivations and, eventually, superseding. The artistic and scientific literature on architecture has developed comparisons of rules mostly within these special clusters. Exceptions are primarily due to technical comparisons and have rarely highlighted the possibility to develop a space of architectural rules as presented in this paper. Our analysis sets the basis for the recognition and identification of such space, and can lead to its systematic investigation via formal ontology and, subsequently, knowledge representation methodologies.

6. Meta-rules in Architecture

An architectural object satisfies a set of rules which are distributed across most, if not all, the eight classes identified in the previous section. Many of these rules are selected because of the initial requirements, the environment in which the object is placed (type

of land, urban context), the architectural style of reference and the cultural-social period. Not all these rules need to be explicitly considered at design time. Others are consequences of the combination of the explicitly chosen rules since many of these deals with intertwined architectural aspects like, e.g., spatial, material and structural rules. The architect applies several strategies to overcome the problem of rule interactions and these strategies require the introduction of *meta-rules*. In case of conflicts, the architect tries to change or reinterpret the rule, for example by applying the rule to a limited subclass of situations thus weakening its applicability. We can show this by comparing architectural rules with standard logical rules.

In classical logic from a rule of form "A implies C", it follows that "A and B imply C" (logically speaking, this is the rule of weakening on the left). This result is not always true in architecture. Assume that we have a rule: "if X is a cornerstone not directly supported by a wall, then X itself is directly supported by a column" which was accepted up to the middle of the 20th century. As seen above, in classical logic this rule implies the following: "if X is a cornerstone not directly supported by a wall and the weight it supports is distributed to other columns or walls, then X itself is directly supported by a column." The latter rule, not being enforced by physical laws, is an architectural rule[3] and can be accepted or rejected by the architect (Fig. 1). Actually, the Modern Movement [18] adopts this rule: "if X is a cornerstone not directly supported by a wall and the weight it supports is distributed to other columns or walls, then X itself must not be directly connected to a column". To sum up, the architect may decide to change the architectural rules she takes as reference by rejecting a weakening meta-rule so to generate a new rule system (and thus a new deign space) where "A implies C" and "A and B does not imply C", at least for some type of statements A, B and C.

Similarly, the architect can modify a rule by questioning the broadening of its consequences (in classical lingo, weakening on the right). Take a traditional rule with logical form "A_0 implies B_0": "if the city gate is closed, then it is not possible to enter / exit the city." Compare this to a modern rule, due to a change of use and status of the city door, with form "A_0 implies C_0": "if the city gate is closed, then one can still move all around the gate." (Fig. 2). These two rules can be combined into the rule "A_0 implies B_0 or C_0": "if the city gate is closed, then it is not possible to enter / exit the city, or one can still move all around the gate" which is logically sound but architecturally pointless. The reason is that statements B_0 and C_0 carry different architectural understandings (background assumptions) which are not just different, they are incompatible. Indeed, if a rule is not capable to provide a sense of guidance and prescription (as the rules we started with), it is useless to the architect.

Our analysis of the history of creativity in architecture leads us to identify several types of architectural meta-rules:

- strengthen/weaken the initial conditions for the application of the rule
- strengthen/weaken the consequences of the application of the rule

[3]This rule became an architectural choice because of technology evolution. Yet, only a couple of centuries after the technology was made available we started having designs where the rule was broken. This shows that the mere possibility of breaking an architectural rule does not suffice, we still need an architect's act of creativity to do it.

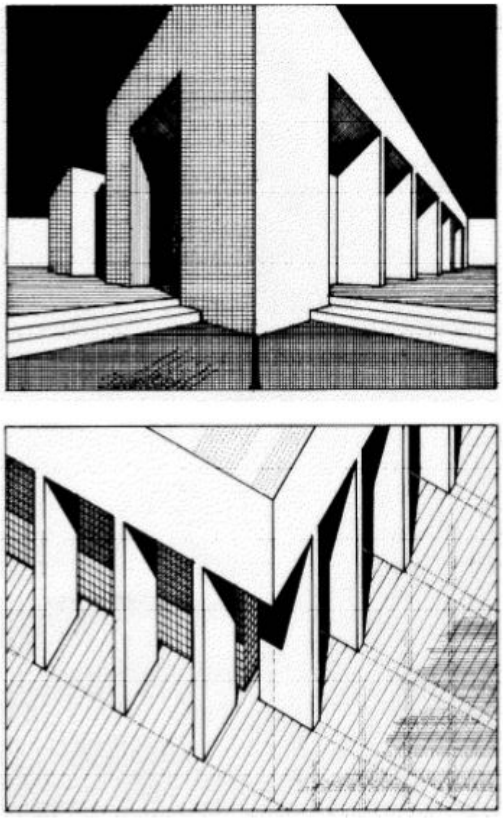

Figure 1. Angle - unit solution - full (top) and Angle - unit solution - vacuum - linear support (bottom), from [6].

- divide the rule in subcases with different conditions/consequences (specialization of the rule context)
- maintain a rule only apparently (i.e., maintain the perception of the rule)[4]
- apply some of the rules at a different level of granularity (including using a rule as a meta-rule)
- substitute a rule with a new one (e.g. when new technologies allow for innovative solutions)

These types do not cover all the aspects related to different ways to elaborate the corpus which can be the result of a mix of different reasoning types like abduction, deduction, and induction. Finally, we do not tackle here how the architects make the choice of which of these rule types to use and the motivations for it, after all this is where the architect exercises her creativity and our focus in this paper is limited to the space of architectural rules and meta-rules.

[4] "Because architecture aims to please the sense, and if the sense is deceived, as frequently happens, into judging a straight object to be crooked, a horizontal one to be inclined, and a large one to be small, additions and compensations must be made in order to satisfy and oblige it and supply what it mistakenly sees lacking." [12].

Figure 2. Namdaemun gate (Seoul, S. Korea), from http://footage.framepool.com.

7. Conclusions

An architectural grammar is a summary of the domain knowledge comprising architectural elements and the rules for their appropriate use to accomplish a task [15]. Unfortunately, rules in architecture are not introduced in a clear way. They are often interpreted within an architectural type, and this latter notion, even though called 'the constitutive world of architecture' [22], is still not well understood. Once an architectural grammar has been fixed, architects follow the rules in it with some freedom, practically changing the grammar itself. This is an act of creativity, a leading factor in the architectural process.

After discussing these difficulties, we have proposed a classification of architectural rules which, based on ontological analysis, objectifies and disconnects them from the usual contextual reading. In this way the relationships (and their interdependencies) among the rules can be identified and studied in a context-independent manner. When applied in a project, the rule is again contextualized, a process that introduces new dependencies related to the context. Having started from the objective classification, it is now easier to understand the source(s) of the conflict between rules, and to coherently choose a suitable strategy to overcome it.

This paper has presented an initial framework to rethink architecture as a discipline of rules and meta-rules which can make it suitable to formal analysis and exploitation, and has practically showed how creativity can find its place in a scientific domain like that of rule-based systems. In the future we plan to consolidate and validate the proposed rule classification. As mentioned in the introduction, we are also working on a general notion of architectural type which would make possible to integrate architectural types, architectural rules and meta-rules in a unified view. The framework we envision could eventually lead to a radical change in the way architecture is taught, and could guide the integration of CAD systems with AI methodologies to support creative thinking as discussed, for instance, in [17,14].

References

[1] P. Abreu. The vitruvian crisis or architecture, the expected experience, on aesthetical appraisal of architecture. In *Proceedings XX Congress, International Association of Empirical Aesthetics, Chicago*, 2008.

[2] S. Borgo and C. Masolo. Foundational Choices in DOLCE. In S. Staab and R. Studer, editors, *Handbook on Ontologies*, pages 361–381. Springer Verlag, 2nd edition, 2009.

[3] Steven C. Bourassa. A paradigm for landscape aesthetics. *Environment and Behavior*, 22(6):787–812, 1990.

[4] H. Broch. Os sonâmbulos [1928-1931]. *Degradação de Valores 2 e 3*, 1965.

[5] L. Corbusier. *Towards a new architecture*. Courier Corporation, 1986.

[6] A. Di Chio. I materiali architettonici della progettazione. Corso di Architettura Tecnica, corso di laurea in ingengeria civile, Università degli Studi di Reggio Calabria, 1996.

[7] J.N.L. Durand. Nouveau précis des leçons d'architecture. Chez l'auteur a l'Ecole Impériale Polytechnique, 1813.

[8] J. Elster. *Ulysses unbound: Studies in rationality, precommitment, and constraints*. Cambridge University Press, 2000.

[9] S. Fisher. Philosophy of architecture. *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, winter 2016

[10] B. Gaut. The philosophy of creativity. *Phil. Compass*, 5(12):1034–1046, 2010.

[11] N. Guarino. Formal ontology in information systems. *Second International Conference on Formal Ontology in Information Systems*, pages 3–15. IOS Press, 1998.

[12] G. Guarini. *Architettura civile*. 1737.

[13] L. Kahn. Architecture is the thoughtful making of spaces. *Perspecta*, pages 2–3, 1957.

[14] F. A. Lisi. Will AI ever support design thinking? In *AIDE workshop at AI*IA*, Vol. 1473, pp. 33–40. CEUR Workshop Proceedings, 2015.

[15] W. J. Mitchell. *The logic of architecture: Design, computation, and cognition*. MIT press, 1990.

[16] T. Morawetz. Wittgenstein's lectures, Cambridge 1930-32, *International Studies in Philosophy*, 14(1):111–113, 1982.

[17] P. Pauwels, . De Meyer, and J. Van Campenhout. Design thinking support: information systems versus reasoning. *Design Issues*, 29(2):42–59, 2013.

[18] Nikolaus Pevsner. *Pioneers of the modern movement from William Morris to Walter Gropius*. Faber & Faber, 1936.

[19] D. Pisani. L'architettura è un gesto: Ludwig Wittgenstein architetto. Quodlibet ed., 2011.

[20] J.C. Pomerol. Artificial intelligence and human decision making. *European Journal of Operational Research 99*, 1 (1997), 3–25.

[21] G. Rabino, D. Borri, and R. Stufano Melone. Creativity in architecture: the cognitive process. *Int. J. Hous. Sci*, 38(4), 2014.

[22] A. Rossi. *L'architettura della città*. Marsilio, Padova, 1966.

[23] J. Ruskin. *The seven lamps of architecture*, volume 521. John B. Alden., 1885.

[24] D.A. Schon. *The reflective practicioner*, Vol. 1. Basic books New York, 1983.

[25] H.A. Simon. *The sciences of the artificial*. MIT press, 1996.

[26] G.A. Wiggins. Searching for computational creativity. *New Generation Computing 24*, 3 (2006), 209–222.

[27] L. Wittgenstein. *The blue and brown book*. Blackwell, Oxford, 1958.